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치의학석사 학위논문

Early diagnosis of jaw osteomyelitis by easy digitalized panoramic analysis

파노라마 영상 분석을 통한 악골 골수염의 조기 진단

2018 년 1 월

서울대학교 치의학대학원

치의학과

박 무 성

Early diagnosis of jaw osteomyelitis by easy digitalized panoramic analysis

지도교수 김 성 민

이 논문을 치의학 석사학위논문으로 제출함

2018 년 1 월

서울대학교 치의학대학원

치의학과

박 무 성

박 무 성의 석사학위논문을 인준함

2018 년 1 월

위 원 장 명 훈 (인)

부 위 원 장 김 성 민 (인)

위 원 양 훈 주 (인)

Abstract

Osteomyelitis is an intraosseous inflammatory disease and it is characterized by progressive inflammatory osteoclasia and ossification. Its most typical pathogenesis is bacterial infection and it may be induced by trauma, radiation or specific drug as well. As treatment of osteomyelitis, early treatment by antibiotics with accurate diagnosis is the best way. Development of medical science and increased oral sanitation contributed to reducing prevalence of maxillary osteomyelitis for the past couple of decades. Recently, a new type of maxillary osteomyelitis being induced by drug called bisphosphonate related osteonecrosis of the jaw (BRONJ) or osteoradionecrosis which secondarily induced by radiotherapy is represented.

Taking panoramic radiograph is a routine process for patients who visited dental clinic at the first time. Possibility of quantitative analysis is on the rise to assist interpretation of osteomyelitis in this study. The objective is to perform early diagnosis of osteomyelitis on digital panoramic radiograph using basic function provided by PACS that is a program showing radiographic image. This study was performed by targeting total 95 patients whose symptom was confirmed as osteomyelitis under clinical, radiologic, pathological diagnosis at SNUDH oral & maxillofacial surgery for total 11 years from 2008 to 2017. Above patients with

osteomyelitis were classified under clinical, radiological and pathological diagnosis and it was divided into 5 categories including osteoradionecrosis (ORN), bisphosphonate-related osteonecrosis of jaw (BRONJ, suppurative/sclerosing type) and bacterial osteomyelitis, (suppurative/sclerosing type).

The photographic density in a certain area in digital panoramic radiograph was measured by using 'measure area rectangle' that is one of basic function in INFINITT PACS®(INFINITT Healthcare, Seoul, Korea) being used at SNUDH among PACS. Photographic density of both sides was compared by dividing digital panoramic radiograph of the patients with osteomyelitis based on median line. Randomly sampled 117 persons who did not receive diagnosis of osteomyelitis by visiting SNUDH oral & maxillofacial surgery from 2008 to 2017 were targeted as control group (WNL). Conditional inference tree, which is one type of decision making tree was being generated with program R as a statistical analysis. Statistical significance was measured in comparison among suppurative type and sclerosing type of BRONJ and bacterial osteomyelitis by t-test with SPSS.

In conditional inference tree being generated by obtained data, in case that average value difference exceeded 54.49 and min value difference was fewer than 54.49 and bigger than 12.81 and min value difference exceeded 39, such result is also suspicious of osteomyelitis. Along with this result, the fact that disease could be correctly classified based on probability of 88.1% as a result.

There is no difference in photographic density value of BRONJ and bacterial osteomyelitis. This result means that it is unable to classify BRONJ and bacterial osteomyelitis by analyzing panoramic radiograph quantitatively as existing researches. Significance of this study is that it would be reasonable to measure photographic density by basic function only being used in PACS and use its data as assistant means while diagnosing osteomyelitis.

Keywords : early diagnosis, panoramic analysis, osteomyelitis of jaw, decision making tree

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Contents

I. Introduction

II. Materials and Methods

II-1. Data acquisitions

II-2. Statistical processing

III. Result

III-1. Comparison between osteomyelitis patient group with control group

III-2. Comparison between bacterial osteomyelitis patient and BRONJ patient group with control group

III-3. Comparison between osteoradionecrosis patient, bacterial osteomyelitis patient and BRONJ patient group with control group

III-4. Statistical significance verification between suppurative type osteomyelitis patient group and scletosing type osteomyelitis patient group

III-5. Statistical significance verification among suppurative type in BRONJ patient group and bacterial osteomyelitis patient group

III-6. Statistical significance verification among sclerosing type in BRONJ patient group and bacterial osteomyelitis patient group

IV. Discussion

V. Conclusion

References

Tables

Figure legends

Figures

Abstract in Korean

I. Introduction

Osteomyelitis is an intraosseous inflammatory process including cortex bone and periosteum which is characterized by the progressive inflammatory osteoclasia with ossification.[1,2] Osteomyelitis could be occurred at any place of human bone including femur, humerus or jaw. Its most typical pathogenesis is bacterial infection such as *Staphylococcus aureus* or *Mycobacteria* and it may be induced by trauma, radiation or specific drug as well.[4,5]

Typical clinical symptom of patient with osteomyelitis is edema, pain, or edema concurrent pain and formation of fistula. Radiologically, radiographic or radiopaque image of which boundary is not clear may be represented.[6] As treatment of osteomyelitis, early treatment by antibiotics with accurate diagnosis is the best way and intravenous injection rather than oral medication sometimes shows better prognosis. If osteomyelitis is confirmed by tissue biopsy, surgical approach of removing infection source, pus and administration of antibiotics at the same time are recommended for better prognosis. But if early diagnosis was failed or suitable type of antibiotics was not used, prognosis may prove to be unfavorable by increasing of focus or spreading of infection to other bone site.[7]

Osteomyelitis of maxillary bone is an important disease taking up considerable portion in patients visiting oral & maxillofacial surgery

in spite of technical development of dental area and development of antibiotics.[7] Development of medical science and increased oral sanitation contributed to reducing prevalence of maxillary osteomyelitis for the past couple of decades. Recently, a new type of maxillary osteomyelitis being induced by drug called bisphosphonate related osteonecrosis of the jaw (BRONJ) or osteoradionecrosis which secondarily induced by radiotherapy is represented.[8] Bisphosphonate related osteonecrosis of the jaw (BRONJ) was reported by Marx in 2003 for the first time and from 2006, it was extensively reported for disease etiology and prognosis.[8,9]

Bisphosphonate is frequently prescribed for treating osteonecrosis related diseases such as multiple myeloma, metastatic cancer in bone marrow, prostatic, breast cancer and preventing osteoporosis. Its mechanism is taken place in a way of involving in metabolic process with osteoclast as medium and it affects alveolar bone as well.[10] IV injected or orally administered bisphosphonate with secondary infection by tooth extraction or tissue biopsy may create BRONJ. [11]

The standard of BRONJ diagnosis is established in total 3 cases based on summary report of 2009 by Korean Endocrine society, KSBMR, the Korean Society of Osteoporosis and KAOMS: (1) A case that exposed maxillary bone was not treated for over 8 weeks, (2) A case of a patient who has medical history of bisphosphonate medication or who is under medication now, (3) A case of having

received radiotherapy to maxillary bone. A patient under BRONJ 0 stage exceptionally complains of nonspecific symptom only without bone exposure.[12] When placing BRONJ on existing osteomyelitis classification system, it is classified as an independent item in view of its features of bone consolidation being progressed around such site and osteonecrosis concomitant suppuration is occasionally concurrent and in many cases. (Table 1)

At present, diagnostic process of osteomyelitis is primarily taken place through panoramic radiographing, oral cavity photographing and clinical diagnostic examination.[7] Among these, this study paid attention to panoramic radiograph. Since its first development in 1991, digital panoramic radiograph has been effectively used in general examination confirming structure and condition of maxillary bone.[13] Among traditional plain radiographs, panoramic radiograph is a sole means by which information of maxilla and mandible could be obtained at the same time. That is why it is used for identifying and diagnosing general focus of maxillary bone and plays a pivotal role in diagnosing osteomyelitis even though it is unable to diagnose osteomyelitis independently.[14,15] As findings of osteomyelitis that could be found in panoramic radiograph, increased thickness of alveolar lamina dura, sclerogenic variation around mandibular canal, sclerogenic variation of maxillary bone and confirmation of osteoclasia and bone pattern could be cited.[7] Above characteristics are findings that could be confirmed in general osteomyelitis but at an early stage when 4−8 days are passed after onset of

osteomyelitis, any sign may not be found in diagnostic radiograph.[16] At hospital, they decide whether additional radiographic examination or clinical examination should be performed based the reading result of relevant medical staff.

During the time when a method of being able to provide tomographic image was not available like CT, panoramic radiograph was a sole means of diagnosis and prognosis follow-up. If HD CT is used, through identifying necrosis level of cortex bone or positioning sequester, resection level of necrotized bone could be determined but panoramic radiograph is an excellent assistant device delivering a lot of information at an early stage and has an excellent function in observing prognosis.[7]

Along with development of PACS (Picture Archiving Communication System), prognosis observation function like this has been further strengthened. PACS is computer based system being designed by the author in order to make diagnostic process easy. Diagnosis is supported by ensuring heady access by attaching Digital Imaging and Communications in Medicine (DICOM) including X-ray, MRI, CT to Electronic Medical Record (EMR) of the patients and having operator confirm the contents read by the reader.[17] Actually, there is a research result that since introduction of PACS, doctors showed higher efficiency in their diagnostic process.[18] Market of this system having been developed in 1980 for the first time has been grown consistently and at present, a lot of university

hospitals adopted this system and its using frequency at dental clinic is on the rise.[17,19]

If findings of osteomyelitis are found in patients visiting dental clinic as a result of diagnosis through panoramic radiograph and ocular inspection, referring to hospital is one of the important duties of the dentist. On the other hand, as CT equipment or a separate image dentistry reader for detailed examination is rare in dental clinic, there may be a difficulty in reading osteomyelitis. In addition, it is considered that when reading osteomyelitis by image dentistry reader at dental clinic, evidence supporting such reading would increase reading accuracy. Under this background, through this study, osteomyelitis diagnosis of the dentists is intended to be supported by providing osteomyelitis diagnosis key through quantitative approach in relatively simple way. In particular, in this study, its objective is to perform early diagnosis of osteomyelitis on digital panoramic radiograph using basic function provided by PACS that is a program showing radiographic image.

II. MATERIALS AND METHODS

This study was performed by targeting total 98 patients whose symptom was confirmed as osteomyelitis under clinical, radiologic, pathological diagnosis at SNUDH oral & maxillofacial surgery for total 11 years from 2008 to 2017. A case of being clinically diagnosed as osteomyelitis even though not diagnosed as osteomyelitis radiologically due to technical limitation was not included in the study. Total 95 patients became target of final research excluding 3 cases that were concluded as non-osteomyelitis under clinical and pathological diagnosis even though possibility of osteomyelitis was mentioned radiologically.

Patients with osteomyelitis were classified under clinical, radiological and pathological diagnosis and it was divided into 5 categories including osteoradionecrosis (ORN), BRONJ, suppurative or sclerosing type of bacterial osteomyelitis. In particular, for ensuring active comparison, BRONJ that is non-suppurative was unavoidably classified into two categories. A case that fistula or pus is formed while necrotized osseous tissue is clearly exposed, it was classified as suppurative and the other case that sclerosing osseous tissue is exposed without necrotized tissue is not present, it was classified as sclerosing type. (Table 2)

II-1. Data acquisitions

Photographic density of a certain area in digital panoramic radiograph was measured by using measure area rectangle that is one of basic function in INFINITT PACS of INFINITT Healthcare being used at SNUDH among PACS.(Fig. 1)

If using function of measure area rectangle, min., max., av., value of photographic density in a certain area could be measured in panoramic radiograph and CT. If certain area is designated, Area, Min, Max, Avg, SD, Sum, Length value are deduced and it means area, min. max., av., value, sum of photographic density in an area and length of area circumference.

Independent variable that could be directly designated by the user among them is area and length and if controlling these factor, region of interest (ROI) having same size for each digital panoramic radiograph could be designated. (Fig. 2) Min., Max., Avg., being deduced as dependent variable are expressed as a value between min −240 and max 2640 and the more photographic density value being expressed at this time is low, it is radiopaque and the more such is high, it is radiolucent (Fig. 3). SD is turned out as the same value if additional option is not requested separately and in case of Sum, it means total photographic density value of all the pixels in the area but in this study, above two values were not used. (Fig. 4)

In a process of deducing photographic density, its value is represented as Hounsfield unit in CT and raw value in panoramic

radiograph. In case of CT, the photographic density is being readjusted as Hounsfield unit through a process of standardization every day so that water is 0 value. So it could be assigned by absolute value only. However, in radiograph, there is no such standardization process so comparison of absolute value among different images is meaningless due to an error in a process of moving osseous tissue from 3D to 2D depending on posture or angle at the time of image photographing.

Particularly the fact that same value is not represented even though photographic density at the same position is measured when photographing same patient twice (Fig. 5). On the other hand, when comparing each part in one sheet of panoramic photograph, it is considered to be relatively standardized. Comparing photographic density of two different parts in one image should be standardized enough so basically clinicians have been used panoramic radiograph in diagnostic process.

Under this background, in this study, photographic density of both sides was compared by dividing digital panoramic radiograph of the patients with osteomyelitis based on median line. Min, Max, Avg value in each area were recorded by designating same rectangular ROI of 100mm^2 to opposite maxillary bone based on median line after designating such ROI based on focus. As such ROI was unable to be designated accurately due to manual work, error was minimized by making one panoramic radiograph have rectangular ROI area and length of both sides while measuring area of 100mm^2

by rounding off at first digit of decimal point. As the value obtained like this is not meaningful as absolute value as mentioned hereinabove, difference value (SUB) being obtained by subtracting Min, Max, Avg value of normal persons from that of area with focus was designated as representative value of each image.

In order to compare each image result with finally obtained difference value (SUB), a case of randomly comparing left/right side in normal digital panoramic radiograph without osteomyelitis was used as control group (WNL). At this time, randomly sampled 117 persons who did not receive diagnosis of osteomyelitis by visiting SNUDH oral & maxillofacial surgery from 2008 to 2017 were targeted. Male was 59 persons, female 58 and average age was 48.9 years old. Among patients sampled as control group, 45% visited for implant, 40% for tooth extraction and remaining 15% maxillary sinus surgery, plate removal, curettage. In control group also, photographic density was measured at the symmetric point by dividing panoramic radiograph in left, right in the same way as patients group with osteomyelitis. Difference of left, right side Min, Max, Avg value being obtained by measurement was designated as representative value of each image.

II-2. Statistical processing

Data being obtained through data acquisition method of 2.2 was finally statistically processed by mainly using decision making tree and statistical processing method of T-test.

Decision making tree is one of data mining analysis techniques and it is a method of classifying or predicting analysis target group to be researched into some small groups based on decision making rule. As analysis process is classified and expressed by tree structure, it has an advantage that its analysis method could be understood and explained without difficulty if comparing it with analysis method of discriminant analysis, regression analysis, neural networks.[20]

Decision making tree is branched to left side in case of 'Yes' to the question of 'Is variable X smaller than constant c when comparing the former with the latter?' and right side in case of 'No'. Each branched unit is called node relative superordinate node is called parent node, subordinate node child node. Branching should be always achieved so that purity of child node is higher than that of parent node.[21]

Through this, decision making tree model is finally discriminated so that a probability that given outcome would be included in each category is obtained or each result value would be included in category having the highest possibility.[20, 21] Being inspired by this point, this study was intended to be helpful for prediction and

diagnosis of osteomyelitis by using decision making tree being generated based on existing presented data classification when photographic density data of potential patient was presented in the future. R was used as a program for preparing decision making tree. R has an excellent function in the fields of computer language for statistical analysis and graphic, data processing as environmental system, statistical analysis and graphic. Since its development by Ross Ihaka and Robert Gentleman of Auckland University for the first time, it has been utilized in diversified fields and recently, it is also frequently used for statistical analysis.

This result stems from favorable universality of software itself as contrary to numerous commercial software costing thousands or tenth of thousands dollars, it is free of charge and its source code is totally disclosed. [22] R system has a big characteristic that it handles data processing and analysis work as dialogue type and by using this characteristic, self-significance test was performed. Decision making tree presents certain classification method and in order to verify how much such method has useful value, confirming the result of performing classification by using this method would be the best way.

However, due to limitation of data, research progression like this is very difficult job. Therefore, it is commonly used to simply verify significance of decision making tree by using prepared data after making decision making tree followed by excluding certain part of total data. Error was briefly solved by setting data quantity as 0.8,

that is 80% in interactive mode analysis of R system and by using remaining 20% data, type 1 & 2 error were verified through significance verification in the future.

In this study, conditional inference tree was performed by using R version 3.2.3(2015-12-10). Conditional inference tree analysis is an important variety of classic decision making tree analysis method of basic form as mentioned previously and it has characteristic that a node is made to be branched based on significance test. In case of using this method, it is expected that relative size of overall group could be reduced and more significant result than decision making tree analysis method could be obtained.[20,21]

First, conditional inference tree model of patient group of osteomyelitis and control group was analyzed. At this time, in case of patient group of osteomyelitis, difference value of photographic density shows negative number depending on suppurative type or sclerosing type. This is attributable to a method being used in this study and when comparing large group of patients with osteomyelitis with control group, comparing only size of difference of photographic density of focus regardless of its degree is normal classification method.

First, at the time of generating decision making tree model, absolute value of all the data was used. Second, comparison of patient group showing characteristics of suppurative type in bacterial osteomyelitis and BRONJ, union sets (B1+C1) of osteoradionecrosis and control group (WNL) was performed

through conditional inference tree. In order to compare average of two samples being extracted from different population, T-test was performed by using SPSS version 21 (release 21.0.0.0). T-test is an analysis method of verifying whether two groups show significant difference statistically and it could be utilized when variance of population is unknown. In particular, generally T-test could be used when number of sample is limited.[23] In this study, a case that suppurative type is represented in BRONJ (B1), suppurative subtype of bacterial osteomyelitis (C1) and sclerosing type in BRONJ (B2) and sclerosing subtype of osteomyelitis (C2) were compared respectively. By comparing B (B1+B2) with C (C1+C2) group as major premise, above comparison was performed after first confirming whether there is clear difference between two groups at the time of T-test. Significance probability was set as 0.01 ($p<.01$) and in case of all the comparisons, that there is no difference among mean value being extracted from each group was defined as null hypothesis.

III. RESULTS

Clinicopathologic data of patient with osteomyelitis was presented in Table 3, 4, and 5. That of normal control group was presented in Table 6. For convenience sake, in case of patient with osteomyelitis, data was summarized based on disease type. Male was 35, female 60 among total 95 patients who visited for osteomyelitis and their average age was 63.52±15.93 years old and it was significantly different with randomly extracted normal patient group(Table 7). Affected site of osteomyelitis was right mandible (46.3%, n=44) followed by left mandible (31.6%, n=30). In case of dividing mandible/maxilla into two arches, such disease was more occurred in mandible (86.3%, n=82) than maxilla (12.7%, n=12). It was occurred in both mandible and maxilla for 1 person. When observing by each detailed classification and discussing a case of bacterial osteomyelitis only, average age of 58.42±16.45 was represented and most affected site was right mandible (46.7%, n=28). In case of BRONJ, average age of 73.19±9.03 was represented and the most affected site was right mandible (45.2%, n=14). In case of osteoradionecrosis, average age of 65±14.71 was represented and the most affected site was right mandible (50%, n=2) (Table 8).

Most frequently performed therapeutic method in this study targets was saucerization (n=52) and in case of medication control, it was followed by mandibulectomy and maxillectomy (n=7)(Table 9).

III-1. Comparison between Osteomyelitis patient group with control group(WNL)

First, all 95 osteomyelitis data under 3 hierarchical classifications was compared with 114 data of normal patient as control group (n=209). Total 167 data excluding 42 data being randomly sampled for significance test was used for formation of decision making tree. All the raw materials were analyzed by taking absolute value (Fig. 6).

First branching of conditional inference tree was achieved through a confirmation whether average value difference of photographic density exceeds 54.49. In case of exceeding such value, second branching was achieved through a confirmation whether min value difference of photographic density exceeds 31 and in case of 31 being exceeded, 100% was represented as osteomyelitis (n=61). In case that min value difference was below 31, 85.7% (n=6) was proved to be normal, 14.3% (n=1) osteomyelitis. In case of first branching where average value difference is below 54.49, second branching was achieved through a confirmation whether min value difference exceeds 39.

In case of below 39, 98.7% (n=77) was normal and 1.3% (n=1) was osteomyelitis. In case that min value difference is below 39, final branching was performed by confirming whether average value difference exceeds 12.81. In a node where min value difference was below 12.81, total 100% (n=8) was normal and in case that min

value difference was between 12.81-54.49, 53.8% (n=7) was normal, 46.2% (n=6) was represented as osteomyelitis.

At the time of verifying significance, 37 data among total 42 was classified without error and a case that osteomyelitis was mistakenly classified as normal was 5 cases (Table 10). This result means that when using above conditional inference tree, based on probability of 88.1%, correct classification could be performed.

III-2. Comparison between Bacterial Osteomyelitis + BRONJ(Suppurative type OM, B1+C1) and control group(WNL)

In bacterial osteomyelitis and BRONJ group, 40 data applicable to suppurative type osteomyelitis was compared with 114 normal patient data (control group). Decision making tree was generated by using total 123 data excluding 20% for significance verification (Fig. 7).

Conditional inference tree was first classified as suppurative type osteomyelitis if average value difference of photographic density exceeds 49.64. In the node being branched like this, osteomyelitis was represented at the rate of 96.7% (n=29) and normal of 3.3% (n=1) was included. A group of which average value difference was same or fewer than 49.64 was branched into two nodes depending on whether min difference is bigger than -28. In a node of which min value difference is below -28, normal of 75% (n=6) and suppurative type osteomyelitis of 25% (n=2) were represented.

In case that min value difference exceeds −28, branching was represented once more depending on whether min value difference is bigger than 60. In a node in which min value difference was bigger than 60, 85.7% (n=6) was classified as normal, 14.3% (n=1) as suppurative type osteomyelitis. Finally, in a nod ein which min value difference is between −28 and 60, only normal was present (100% (n=78).

At the time of significance verification, 28 data was classified without error among total 31 data and in 3 data, suppurative type osteomyelitis was mistakenly classified as normal (Table 10). This result means that when using conditional inference tree, correct classification could be performed based on probability of 96.8%.

III−3. Comparison between Osteoradionecrosis + Bacterial Osteomyelitis + BRONJ(Sclerosing type OM, B2+C2+A)and control group(WNL)

In two groups including osteoradionecrosis/bacterial osteomyelitis and BRONJ, 55 data applicable to sclerosing type osteomyelitis was compared with 114 normal patient data that is control group (Fig. 8).

Conditional inference tree classified first node depending on whether avg. value difference of photograhic density exceeds −72.85. A case that avg. value difference was below −72.85 was branched to final node depending on whether min value difference exceeds −68. In case that avg. value difference was below −72.85

and min. value difference was below −68, 100% (n=33) was classified as sclerosing type osteomyelitis. If min value difference exceeds −68, 28.6% (n=2) was represented to be normal, 71.4% (n=5) sclerosing type osteomyelitis.

When observing that avg. value difference exceeds −72.85 by going back to first node, it is again branched by confirming whether min value difference exceeds 60. In case that avg. value difference exceeded −72.85 and min value difference exceeded 60, 60.0% (n=6) was classified as normal, 40% (n=4) as sclerosing type osteomyelitis. A case that min value difference was below 60 was additionally branched by confirming whether min value difference exceeds 34.

In case that min value difference was below −34, 66.7% (n=6) was classified as normal and 33.3% (n=3) as sclerosing type osteomyelitis. In case that min value difference was over −34 and below 60 was branched once more by confirming whether min value difference finally exceeds 26. In case that max value difference was below 26, 100% (n=69) was normal and in case that max value difference exceeds 26, 85.7% (n=6) classified as normal and 14.3% (n=1) as sclerosing type osteomyelitis.

At the time of significance verification, 32 data among 34 was classified without error and in 2 cases, normal was mistakenly classified as sclerosing type osteomyelitis (Table 10). This result means that when using above conditional inference tree, correct classification could be performed based on probability of 94.1%.

III-4. Statistical significance verification between Suppurative type OM(B1+C1)and Sclerosing type OM(B2+C2)

T-test was performed based on a null hypothesis that there is no difference in avg, max, min value in two groups including suppurative type OM and sclerosing type OM (Table 11, 12, 13). As significance probability in all avg, max, min value is bigger than 0.01 in above two groups, above null hypothesis is dismissed. There is a respective difference in avg, max, min value in above two groups.

III-5. Statistical significance verification among Suppurative type(B1 / C1) in BRONJ and bacterial osteomyelitis

T-test was performed based on a null hypothesis that there is no difference in avg, max, min value of two groups including BRONJ group showing suppurative type OM aspect and bacterial osteomyelitis group showing suppurative type aspect (Table 14, 15, 16).

As significance probability of avg, max, min value of two groups including BRONJ group showing suppurative type aspect and bacterial osteomyelitis group showing suppurative type aspect was smaller than 0.01, above null hypothesis is dismissed. There is no difference in avg, max, min value of above two groups.

III-6. Statistical significance verification among sclerosing type (B2 / C2) in BRONJ and bacterial osteomyelitis

T-test was performed based on a null hypothesis that there is no difference in avg, max, min value of above two groups including BRONJ group showing sclerosing type aspect and bacterial osteomyelitis group showing sclerosing type aspect (Table 17, 18, 19). As significance probability of avg, max, min value of two groups including BRONJ group showing sclerosing type aspect and bacterial osteomyelitis group showing sclerosing type aspect was smaller than 0.01, above null hypothesis is dismissed. There is no difference in avg, max, min value of above two groups.

IV. DISCUSSION

Interpretation of clinical and radiographic analysis result of osteomyelitis

As a result of the study, female (average age: 63.52±15.93) was more affected by osteomyelitis (63.2%, n=60) in mandible (86.3%, n=82). As clarified by existing study, this result is considered to be in line with the fact that morbidity of osteomyelitis in maxilla is fewer than mandible as blood circulation is relatively rich in maxilla.[24]

Decision making tree being generated by comparing patient group with osteomyelitis with normal control group used average value difference and min value difference of radiographic density as classification standard (Fig. 6). In conditional inference tree being generated by obtained data, in case that average value difference exceeded 54.49 and min value difference was fewer than 54.49 and bigger than 12.81 and min value difference exceeded 39, such result is also suspicious of osteomyelitis. Along with this result, the fact that disease could be correctly classified based on probability of 88.1% as a result of significance verification using each conditional inference tree being suggested in Fig. 6 means that it is not significantly deviated from existing common idea of preparing reading report based on probability of 90% at the time of reading radiography. In case that a function that may assist accuracy of

radiography reading is unable to be performed or reading expert is unable to perform reading, its substituted means is considered to be available.

When reading existing radiographic image of osteomyelitis qualitatively, attention shall be paid to the following characteristics. Images showing findings clearly different from normal in panoramic image are characteristics of both in acute and chronic disease and its respective pathologic pattern is different.

In acute osteomyelitis, loss of spongy trabecular bone structure and local radiographic image are represented first. This change of spongy bone pattern is one of key elements when reading osteomyelitis qualitatively.[25] In the tooth, extension of periodontal ligament space or loss of alveolar lamina dura may be accompanied. Radiographic image of which boundary is not clear or sequester is sometimes shown on radiographic image. In this case, osteomyelitis is considered to be passed to chronic stage. [7,26] This reading result depends on experience of experts and as this qualitative reading result is not perfect, it may be required to be supplemented.

When comparing other reading result as there is no report on reading error of osteomyelitis, only 50% consensus was achieved when reading dental root apex related radiographic image of total 253 cases by two conservative dentistry specialists, 3 2nd term residents of conservative dentistry and radiology professor. In addition, when evaluating these cases after 6-8 months, only 75-83% of inspectors made a diagnosis same as the first one.[27]

When giving 24 sheets of panoramic image to total 12 persons including each 3 persons of oral surgery specialist, pathology specialist, radiology specialist and dental doctor and asking them to choose which one among 4 kinds of solitary focus such as ameloblastoma, keratocyst, dentigerous cyst, traumatic bone cyst is applicable to such image, only 56% read such image correctly regardless of additional post-treatment by computer.[28]

Existing researches on radiographic reading of osteomyelitis are limited. According to a research' s clarification, in case of reading acute osteomyelitis radiographically, during first 2 weeks, 3 sheets of radiographic photo among total 4 show normal image and even though extending its range to first 4 weeks, it is so much hard to read image at an early stage as to read pathologic finding in only 3 persons among total 8 patients. In a re-photographed image after passing 4 weeks, pathologic finding could be confirmed clearly.[29]

As observed in above existing researches, it could be confirmed that primarily, accuracy and reproducibility of reading mode for qualitative panoramic image could not be perfect and as just one wrong diagnosis may induce fatal prognosis, supplementary measure shall be taken. In this respect, if osteomyelitis could be diagnosed at an early stage based on probability of 88.1% through a method used in this study, such method could be used under the situation of dental clinicians without radiologist. Furthermore, digitalized analysis can show the ossification state indirectly by the photographic density. In this way, the method has the chance to be

utilized as post-operative regular check of osteomyelitis patients as well.

Result analysis of osteomyelitis sub-classification

As clarified by the result of study, suppurative type OM could generate conditional inference tree by using avg value difference and min value difference of photographic density and as its result, based on probability of 96.8%, patient group could be classified from normal control group. Sclerosing type OM could generate conditional inference tree by using avg value difference and min, max value difference of photographic density and as its result, based on probability of 94.1%, patient group could be classified from normal control group. As photographic density difference of focus site of each patient normal site is biased to one side (positive or negative side), when performing relative classification, it is considered that error may not be significant.

When comparing BRONJ and bacterial osteomyelitis showing photographic density change of similar aspect in panoramic radiograph through T-test (each comparison of B1 and C1 or B2 and C2), there was no significant difference in photographic density. This result means that it is unable to classify BRONJ and bacterial osteomyelitis by analyzing panoramic radiograph quantitatively. There were many attempts trying to segmenting radiologic characteristics of BRONJ in panoramic radiograph and CT but clear

standard was unable to be defined and this fact is in line with the result of this study.[30, 31, 32]

In a study, as it was mentioned that clear standard and detailed classification are required for periosteal reaction, bone thickness and bone density, hard/soft tissue change of patients with osteomyelitis, it is considered to be desirable to provide this standard through required quantitative, qualitative analysis.[32]

Difference with existing quantitative analysis attempt

Quantitative analysis attempt using panoramic image has been made consistently even though such attempt was limited. One method is to suppose bone density by using mandibular cortical width degree, or index and in this method, bone density was guessed by converting a value measuring mandible margin length from mental foramen to gonial angle into proper formula.[33] Klemetti made classification system of bone density at the back side of mental foramen based on this quantitative analysis as a base and this is considered to be an attempt of trying to make significant outcome through quantitative analysis.[34]

There was an effort of standardizing image error depending on posture of the patient at the time of radiographing. As a method of standardizing panoramic radiograph itself from the time of photographing, there is a case of photographing by attaching Nickel stepwedge to casette.[35] Recently, there was a research of analyzing

not standardized panoramic radiograph by using specific software. In a research using Digora, bone density was analyzed by dividing it into photographic density of 254 stages in order to determine prognosis after extracting odontogenic keratocyst. By analyzing panoramic radiograph quantitatively from the research result that maxillary bone density for 6 months after the operation showed significant difference compared with maxillary bone density on 12th month after the operation, bone density could be confirmed.[36]

Quantitative analysis method of photographic density of panoramic radiograph being utilized in existing study has a limitation that a separate pre-treatment or post-treatment was performed for standardization or measurement was made by using additional software for research. It is encouraging that more precise research result could be deduced through above process but it has a disadvantage that directly utilizing data under general treatment situation is almost impossible considering time and resources. Significance of this study is that it would be reasonable to measure photographic density by basic function only being used in PACS and use its data as assistant means while diagnosing osteomyelitis.

Limitations

The biggest limitation of this study is low reproducibility of panoramic radiograph itself. That photographic density, image size or location may be changed whenever photographing depending on

photographing posture and other detailed settings means that reliability of data being obtained through quantitative analysis is questionable. For this objective, it is impossible to perform standardization for all the patients through pre-treatment. However, as mentioned previously, it was confirmed that panoramic radiography is radiographic image being widely utilized as assistant diagnostic tool in the field and function for observing prognosis and so, raising questions for this is like raising doubt about using panoramic radiograph itself.

In case that focus exists in both, not one side, utilization of this method may become difficult but as clarified by this study, as focus existed in one side of left/right is 89.5% (n=85) and it is dominantly bigger than 7.4% (n=7) that is a case of existence in both left, right, there would be no problem. In addition, in order to designate accurate location and size when designating opposite location by bilateral symmetry after designating location and size of focus, considerably skilled technique may be required. In this study, for unity, focus size was compared by placing it on the same line but at the time of actual utilization, it could be used by modification so that total focus would be included. In that case also, whether such work would be fully functional shall be reconsidered.

It is hard to directly discriminate very big periapical lesion, cyst of which boundary is not clear or other positive tumor and osteomyelitis by photographic density information only of radiograph. If diagnosis should be performed based on a principle of

utilizing radiograph together with clinical diagnosis, medical history hearing and visual inspection at the time of diagnosing osteomyelitis by existing method, big program would not be taken place. And in case of focus in which photographic density change is observed in panoramic radiograph, it would be possible to make quantitative diagnostic standard by performing same process for such focus.

V. Conclusion

For the early diagnosis of osteomyelitis, quantitative method of using panoramic radiograph was suggested. In particular, in order to make clinically usable method, a method of enabling quantitative analysis was suggested by PACS program only without using complicated and expensive software.

According to conditional inference tree being prepared as a result of study, in case that new patient shows clinical symptom being suspicious of osteomyelitis, avg value difference is over 54.49 and min value difference is below 31 by measuring photographic density of site being suspicious of osteomyelitis. Acquired panoramic radiograph or avg value difference is between 12.81 and 54.49 min value difference is over 39 can also being suspicious of osteomyelitis. (Fig. 9) Dental clinicians may refer such patient to general hospital or confirm osteomyelitis by laboratory test and tissue biopsy. This method is considered to be usable as assistant means at the time of reading by image dentistry specialist of dental clinic.

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Tables

Table 1. Classification of osteomyelitis

Suppurative Osteomyelitis
Acute suppurative Osteomyelitis
Chronic suppurative Osteomyelitis
Non-suppurative Osteomyelitis
Diffuse sclerosing Osteomyelitis
Focal sclerosing Osteomyelitis
Proliferative periostitis(Garre syndrome)
Osteoradionecrosis
BRONJ

Table 2. Classification system of osteomyelitis in this study

ORN (A)	
BRONJ	Suppurative type (B1)
	Sclerosing type (B2)
Bacterial(Infectious) Osteomyelitis	Suppurative type (C1)
	Sclerosing type (C2)

Table 3. Clinicopathologic data of osteoradionecrosis patients

Number	Sex	Age	Focus	Clinical exam	Radiograph interpretation	Pathologic exam / Clinical diagnosis	Subtype	Treatment	MIN (focus)	MAX (focus)	AVG (focus)	MIN (WNL)	MAX (WNL)	AVG (WNL)	MIN (DIF)	MAX (DIF)	AVG (DIF)
693373	F	46	Lt&Rt mand.	ESR(H)	osteomyelitis	Osteoradionecrosis	sclerosing	partial maxillectomy	1553	1972	1794.71	1646	2079	1903.48	-93	-107	-108.77
703131	M	75	Rt mand.	WNL	osteomyelitis	Osteoradionecrosis	sclerosing	saucerization	1573	2116	1852.77	1671	2057	1938.17	-98	59	-85.4
749728	F	56	Lt mand.	ESR(H), Seg. Neutrophil(H)	osteomyelitis	Osteoradionecrosis	sclerosing	saucerization	1603	2102	1852.37	1675	2181	1946.99	-72	-79	-94.62
858433	M	83	Rt mand.	WNL	osteomyelitis	Osteoradionecrosis	sclerosing	saucerization	1513	1984	1808.88	1722	2065	1913.48	-209	-81	-104.6

Table 4. Clinicopathologic data of BRONJ patients

Number	Sex	Age	Focus	Clinical exam	Radiograph interpretation	Pathologic exam / Clinical diagnosis	Subtype	Treatment	MIN (focus)	MAX (focus)	AVG (focus)	MIN (WNL)	MAX (WNL)	AVG (WNL)	MIN (DIF)	MAX (DIF)	AVG (DIF)
778971	F	73	Lt mand.	WNL	osteomyelitis	BRONJ	suppurative	saucerization	1480	2091	1896.11	1649	2020	1863.72	-169	71	32.39
668160	M	68	Lt mand.	ESR(H), Seg. Neutrophil(H)	osteomyelitis	BRONJ	suppurative	partial mandibulectomy	1573	2076	1832.29	1468	2029	1699.15	105	47	133.14
744201	F	78	Rt mand.	ESR(H)	osteomyelitis	BRONJ	suppurative	I&D	1539	1992	1802.43	1508	1998	1711.27	31	-6	91.16
731633	F	85	Lt mand.	WNL	osteomyelitis	BRONJ	suppurative	saucerization	1764	2085	1889.84	1615	2110	1809.25	149	-25	80.59
764169	F	69	Rt mand.	ESR(H)	osteomyelitis	BRONJ	suppurative	saucerization	1854	2175	2042.27	1671	2102	1933.21	183	73	109.06
801895	F	72	Rt max.	ESR(H), Seg. Neutrophil(L)	osteomyelitis	BRONJ	suppurative	saucerization	1939	2372	2177.43	1882	2319	2118.33	57	53	59.1
852040	F	82	Lt mand.	ESR(H), Monocyte(H)	osteomyelitis	BRONJ	suppurative	saucerization	1809	2110	1980.4	1578	1975	1811.75	231	135	168.65
858916	F	83	Rt mand.	ESR(H)	osteomyelitis	BRONJ	suppurative	saucerization	1789	2119	1985.95	1781	2091	1954.43	8	28	31.52
624651	F	81	Ant max.	WNL	osteomyelitis	BRONJ	suppurative	saucerization	1694	2245	2019.39	1736	2251	2046.65	-42	-6	-27.26
849528	F	82	Rt mand.	ESR(H)	osteomyelitis	BRONJ	suppurative	saucerization	1634	2074	1885.69	1412	1905	1659.8	222	169	225.89
786674	F	91	Rt mand.	ESR(H)	osteomyelitis	BRONJ	suppurative	saucerization	1770	2141	1946.75	1539	1992	1768.66	231	149	178.09
666784	F	60	Ant mand.	ESR(H), MPV(L)	osteomyelitis	BRONJ	suppurative	saucerization	1851	2282	2098.71	1792	2228	1990.94	59	54	107.77
715899	F	72	Lt max.	ESR(H), Seg. Neutrophil(L)	osteomyelitis	BRONJ	suppurative	saucerization	1609	2200	1975.42	1573	2026	1819.49	36	174	155.93
622596	F	72	Lt&Rt mand.	WNL	osteomyelitis	BRONJ	suppurative	saucerization	1632	2119	1904.59	1406	1941	1673.48	226	178	231.11

730285	F	70	Lt mand.	ESR(H)	osteomyelitis	BRONJ	suppurative	medicine	1634	2091	1887.19	1477	1978	1797.1	157	113	90.09
570815	F	52	Rt mand.	ESR(H)	osteomyelitis	BRONJ	suppurative	saucerization	1725	2051	1918.26	1601	2045	1827.81	124	6	90.45
700843	F	75	Rt mand.	ESR(H), Seg. Neutrophil(H)	osteomyelitis	BRONJ	suppurative	saucerization	1677	2034	1882.06	1573	1975	1769.75	104	59	112.31
771291	F	74	Lt mand.	ESR(H), Seg. Neutrophil(H)	osteomyelitis	BRONJ	suppurative	saucerization	1657	2057	1905.74	1471	1826	1653.17	186	231	252.57
782999	F	65	Rt mand.	WNL	osteomyelitis	BRONJ	suppurative	medicine	1809	2175	2002.34	1587	1939	1763.16	222	236	239.18
789300	F	82	Ant mand.	ESR(H)	osteomyelitis, BRONJ	BRONJ	suppurative	sequestrectomy	1764	2147	1973.44	1651	2026	1849.38	113	121	124.06
791175	F	79	Lt max.	ESR(H)	osteomyelitis	BRONJ	suppurative	saucerization	1632	2110	1937.68	1570	2034	1821.78	62	76	115.9
857044	F	68	Rt max.	ESR(H), Seg. Neutrophil(L)	osteomyelitis	BRONJ	suppurative	saucerization	1941	2352	2184.82	1733	2251	2002.18	208	101	182.64
794098	F	74	Rt max.	ESR(H), Seg. Neutrophil(H)	osteomyelitis, malignancy	BRONJ	sclerosing	untreated.	1511	2062	1771.1	1601	2265	1960.84	-90	-203	-189.74
748283	F	61	Rt mand.	WNL	localized osteomyelitis	BRONJ	sclerosing	saucerization	1446	1820	1581.01	1744	2099	1915.54	-298	-279	-334.53
756826	F	82	Lt mand.	WNL	osteomyelitis	BRONJ	sclerosing	mass resection	1553	1964	1779.51	1730	2057	1913.17	-177	-93	-133.66
754924	F	78	Rt mand.	ESR(H)	osteomyelitis	BRONJ	sclerosing	saucerization	1482	1958	1755.99	1634	1964	1820.36	-152	-6	-64.37
796627	F	70	Rt mand.	ESR(H), Seg. Neutrophil(H)	osteomyelitis	BRONJ	sclerosing	marginal mandibulectomy	1370	1840	1580.67	1527	2034	1767.44	-157	-194	-186.77
771877	F	74	Rt mand.	ESR(H)	osteomyelitis	BRONJ	sclerosing	saucerization	1530	1902	1718.41	1744	2062	1922.01	-214	-160	-203.6
761512	F	55	Lt mand.	ESR(H)	osteomyelitis	BRONJ	sclerosing	saucerization	1533	1964	1773.53	1848	2192	2045.58	-315	-228	-272.05
689909	F	60	Rt mand.	WNL	osteomyelitis, BRONJ	BRONJ	sclerosing	sequestrectomy	1432	1865	1612.33	1649	2031	1889.48	-217	-166	-277.15
803174	M	82	Rt mand.	WNL	sclerosing osteitis	BRONJ	sclerosing	sequestrectomy	1223	1716	1488.97	1460	1905	1680.08	-237	-189	-191.11

Table 5. Clinicopathologic data of Bacterial osteomyelitis patients

Number	Sex	Age	Focus	Clinical exam	Radiograph interpretation	Pathologic exam / Clinical diagnosis	Subtype	Treatment	MIN (focus)	MAX (focus)	AVG (focus)	MIN (WNL)	MAX (WNL)	AVG (WNL)	MIN (DIF)	MAX (DIF)	AVG (DIF)
607054	F	69	Lt mand.	WNL	osteomyelitis	osteomyelitis	suppurative	medicine	1908	2251	2118.31	1874	2228	2034.51	34	23	83.8
619954	F	80	Lt max.	ESR(H)	osteomyelitis	osteomyelitis	suppurative	I&D	1820	2274	2053.17	1677	2198	1973.82	143	76	79.35
705686	M	71	Lt mand.	ESR(H), Seg. Neutrophil(H)	osteomyelitis	osteomyelitis	suppurative	saucerization	1772	2124	1983.36	1499	1922	1737.21	273	202	246.15

731265	M	67	Rt mand.	ESR(H)	osteomyelitis	osteomyelitis	suppurative	saucerization	1820	2110	1987.42	1471	1840	1663.73	349	270	323.69
756169	F	70	Lt max.	ESR(H)	osteomyelitis	osteomyelitis	suppurative	saucerization	1846	2189	2026.4	1764	2175	2007.86	82	14	18.54
764446	M	40	Rt mand.	ESR(H)	osteomyelitis	osteomyelitis	suppurative	saucerization	1770	2158	2003.37	1713	2167	1933.95	57	-9	69.42
785809	F	75	Lt mand.	WNL	osteomyelitis	osteomyelitis	suppurative	sequestrectomy	1603	2119	1929.1	1429	2076	1801.1	174	43	128
709453	M	78	Lt mand.	ESR(H)	osteomyelitis	osteomyelitis	suppurative	sequestrectomy	1418	1820	1614.38	1460	1834	1647.79	-42	-14	-33.41
767260	F	83	Lt&Rt mand.	ESR(H)	osteomyelitis	osteomyelitis	suppurative	untreated	1725	2082	1933.41	1634	2065	1878.56	91	17	54.85
602179	M	55	Lt mand.	MPV(H), Seg. Neutrophil(H)	osteomyelitis	osteomyelitis	suppurative	saucerization	1696	2065	1887.69	1606	1874	1743.73	90	191	143.96
263165	F	55	Rt mand.	ESR(H), Seg. Neutrophil(H)	osteomyelitis	osteomyelitis	suppurative	saucerization	1834	2099	1971.01	1665	1978	1826.28	169	121	144.73
612123	M	56	Rt mand.	ESR(H)	osteomyelitis	osteomyelitis	suppurative	saucerization	1595	2212	1936.99	1756	2243	1959.19	-161	-31	-22.2
639287	M	64	Lt max.	ESR(H)	osteomyelitis	osteomyelitis	suppurative	partial maxillectomy	1840	2324	2164.56	1663	2372	2042.84	177	-48	121.72
67244	F	73	Lt mand.	ESR(H), Seg. Neutrophil(H)	osteomyelitis	osteomyelitis	suppurative	saucerization	1809	2172	1999.79	1595	2009	1805.36	214	163	194.43
724643	M	46	Rt mand.	ESR(H), Seg. Neutrophil(H)	osteomyelitis	osteomyelitis	suppurative	saucerization	1556	2003	1808.9	1415	1840	1639.52	141	163	169.38
767276	M	74	Lt mand.	ESR(H)	osteomyelitis	osteomyelitis	suppurative	partial mandibulectomy	1815	2181	2035.11	1801	2121	1980.84	14	60	54.27
787902	F	63	Rt mand.	WNL	osteomyelitis	osteomyelitis	suppurative	saucerization	1764	2144	1997.62	1519	2062	1796.23	245	82	201.39
791385	M	38	Rt mand.	-	osteomyelitis	osteomyelitis	suppurative	Untreated.	1685	2130	1933.05	1634	2110	1818.69	51	20	114.36
808244	F	76	Rt mand.	ESR(H)	osteomyelitis, BRONJ	osteomyelitis	sclerosing	saucerization	1280	1924	1593.86	1440	2054	1757.47	-160	-130	-163.61
663815	M	11	Rt mand.	-	periapical rarefying osteitis	osteomyelitis	sclerosing	endodontic treatment	1688	2161	1941.12	1817	2257	2065.91	-129	-96	-124.79
711938	M	37	Rt mand.	WNL	osteomyelitis	osteomyelitis	sclerosing	saucerization	1764	2183	1983.69	1812	2228	2033.55	-48	-45	-49.86
710148	M	66	Rt max.	ESR(H)	osteomyelitis	osteomyelitis	sclerosing	medicine	1392	1882	1624.36	1460	1950	1731.44	-68	-68	-107.08
724491	F	37	Rt mand.	WNL	osteomyelitis	osteomyelitis	sclerosing	saucerization	1418	1896	1676.6	1567	1958	1760.98	-149	-62	-84.38
662009	F	55	Lt max.	ESR(H)	osteomyelitis	osteomyelitis	sclerosing	sequestrectomy	1437	2102	1813.89	1539	2217	2003.98	-102	-115	-190.09
719918	F	59	Lt&Rt max&mand.	ESR(H)	periapical rarefying osteitis	osteomyelitis	sclerosing	medicine	1370	1837	1616.7	1761	2076	1932.99	-391	-239	-316.29
732316	M	73	Lt mand.	WNL	periapical rarefying osteitis	osteomyelitis	sclerosing	Untreated.	1494	2034	1714.93	1544	1975	1773.36	-50	59	-58.43
748293	F	46	Rt mand.	ESR(H), Seg. Neutrophil(L)	osteomyelitis	osteomyelitis	sclerosing	I&D	1725	2062	1913.24	1877	2234	2081.31	-152	-172	-168.07

763111	M	31	Lt mand.	WNL	osteomyelitis	osteomyelitis	sclerosing	saucerization	1547	2076	1752.77	1725	2079	1932.02	-178	-3	-179.25
310137	F	72	Lt mand.	WNL	osteomyelitis	osteomyelitis	sclerosing	untreated.	1268	1950	1591.62	1440	2003	1664.47	-172	-53	-72.85
694623	F	58	Rt mand.	ESR(H)	sclerosing osteomyelitis	osteomyelitis	sclerosing	Medicine	1646	1975	1807.21	1688	2102	1887.45	-42	-127	-80.24
777410	F	65	Lt&Rt mand.	ESR(H)	sclerosing osteomyelitis	osteomyelitis	sclerosing	saucerization	1646	2065	1817.18	1877	2195	2053.85	-231	-130	-236.67
721744	F	68	Rt mand.	ESR(H)	osteomyelitis	osteomyelitis	sclerosing	mass resection	1488	1832	1682.19	1539	1992	1801.5	-51	-160	-119.31
791596	F	67	Lt mand.	ESR(H), Seg. Neutrophil(L)	osteomyelitis	osteomyelitis	sclerosing	hemimandibulectomy	1418	1975	1739.77	1789	2110	1952.28	-371	-135	-212.51
800281	F	27	Rt mand.	Seg. Neutrophil(L)	sclerosing osteitis	osteomyelitis	sclerosing	Saucerization	1634	1975	1803.82	1750	2029	1903.44	-116	-54	-99.62
806579	M	76	Lt mand.	ESR(H), Seg. Neutrophil(L)	osteomyelitis	osteomyelitis	sclerosing	Saucerization	1587	1967	1774.2	1868	2212	2078.94	-281	-245	-304.74
276618	M	79	Rt mand.	ESR(H), MPV(L)	osteomyelitis	osteomyelitis	sclerosing	partial mandibulectomy	1437	1832	1598.62	1674	2012	1826.86	-237	-180	-228.24
645836	F	39	Rt mand.	WNL	osteomyelitis	osteomyelitis	sclerosing	medicine	1741	2169	1967.1	1801	2167	2026.86	-60	2	-59.76
666554	M	62	Rt max.	ESR(H)	periapical rarefying osteitis	osteomyelitis	sclerosing	Saucerization	1361	2271	1780.37	1592	2251	1926.32	-231	20	-145.95
723283	M	73	Lt mand.	ESR(H), Seg. Neutrophil(H)	osteomyelitis	osteomyelitis	sclerosing	saucerization	1587	2026	1799.39	1767	2093	1953.56	-180	-67	-154.17
773049	M	59	Rt mand.	ESR(H)	osteomyelitis	osteomyelitis	sclerosing	saucerization	1477	1868	1646.73	1587	1910	1740.57	-110	-42	-93.84
787940	M	71	Lt mand.	WNL	osteomyelitis	osteomyelitis	sclerosing	saucerization	1494	1950	1706.82	1547	2026	1820.08	-53	-76	-113.26
811104	F	78	Rt mand.	ESR(H)	sclerosing osteitis	osteomyelitis	sclerosing	saucerization	1246	2051	1570.51	1975	2237	2110.6	-729	-186	-540.09
860223	M	70	Rt mand.	WNL	osteomyelitis	osteomyelitis	sclerosing	saucerization	1502	1975	1708.55	1837	2195	2063.25	-335	-220	-354.7
705034	F	69	Rt mand.	ESR(H)	osteomyelitis	osteomyelitis	sclerosing	cyst enucleation	1322	1778	1509.59	1578	1891	1742.38	-256	-113	-232.79
674308	M	48	Lt mand.	Seg. Neutrophil(L)	osteomyelitis	osteomyelitis	sclerosing	untreated.	1440	1834	1620.08	1502	1936	1716.86	-62	-102	-96.78
649094	M	65	Rt mand.	ESR(H), MPV(H), Seg. Neutrophil(L)	periapical rarefying osteitis	osteomyelitis	sclerosing	untreated.	1761	2212	1994.63	1832	2243	2071.86	-71	-31	-77.23
658742	M	33	Lt mand.	WNL	periapical rarefying osteitis	osteomyelitis	sclerosing	extraction	1584	2164	1868.78	1573	1995	1820.09	11	169	48.69
324612	F	47	Lt mand.	-	periapical rarefying osteitis	osteomyelitis	sclerosing	untreated.	1530	1950	1760.78	1466	2045	1739.86	64	-95	20.92

689332	F	63	Lt&Rt mand.	ESR(H)	periapical rarefying osteitis	osteomyelitis	sclerosing	extraction	1770	2133	1982.82	1677	2040	1889.43	93	93	93.39
627145	M	51	Lt&Rt mand.	ESR(H), Seg. Neutrophil(H)	osteomyelitis	osteomyelitis	sclerosing	medicine	1418	1913	1639.51	1556	2015	1827.55	-138	-102	-188.04
167324	F	34	Lt mand.	-	osteomyelitis	osteomyelitis	sclerosing	untreated.	1663	2000	1822.31	1764	2082	1943.35	-101	-82	-121.04
796801	M	63	Lt mand.	ESR(H), Seg. Neutrophil(L)	osteomyelitis	osteomyelitis	sclerosing	untreated.	1412	1820	1629.77	1443	1978	1748.75	-31	-158	-118.98
809916	F	39	Rt mand.	-	sclerosing osteitis,osteomyelitis	osteomyelitis	sclerosing	extraction	1688	2127	1920.91	2003	2251	2155.04	-315	-124	-234.13
790618	M	60	Rt mand.	Seg. Neutrophil(L)	sclerosing osteitis	osteomyelitis	sclerosing	untreated.	1626	2020	1841.67	1764	2150	1998.19	-138	-130	-156.52
794062	M	57	Rt mand.	WNL	sclerosing osteitis	osteomyelitis	sclerosing	untreated.	1423	1848	1633.69	1609	2057	1886.32	-186	-209	-252.63
781773	F	29	Lt mand.	WNL	osteomyelitis	osteomyelitis	sclerosing	saucerization	1634	1961	1796.78	1764	2062	1917.23	-130	-101	-120.45
532982	M	68	Rt mand.	-	osteomyelitis	osteomyelitis	sclerosing	cyst enucleation	1499	1939	1711.31	1615	2051	1876.03	-116	-112	-164.72
808423	F	80	Rt mand.	ESR(H)	osteomyelitis, BRONJ	osteomyelitis	sclerosing	saucerization	1764	2082	1947.37	1457	2119	1860.85	307	-37	86.52
663189	F	27	Rt mand.	WNL	osteomyelitis	osteomyelitis	sclerosing	saucerization	1423	1908	1636.31	1573	2099	1894.66	-150	-191	-258.35
808245	M	60	Lt mand.	Seg. Neutrophil(L)	osteomyelitis	osteomyelitis	sclerosing	cyst enucleation	1820	2099	1959.02	1657	2015	1864.01	163	84	95.01

Table 6. Data of control group (WNL)

Number	Sex	Age	MIN(WNL1)	MAX(WNL1)	AVG(WNL1)	MIN(WNL2)	MAX(WNL2)	AVG(WNL2)	MIN(DIF)	MAX(DIF)	AVG(DIF)
620090	F	38	1710	2234	2081.82	1792	2245	2069.97	-82	-11	11.85
617934	M	29	1840	2203	2043.01	1789	2181	2020.19	51	22	22.82
615528	M	59	1823	2240	2080.76	1764	2228	2060.56	59	12	20.2
615029	F	19	1922	2231	2088.84	1888	2231	2076.7	34	0	12.14
596791	M	34	1958	2248	2166.46	1953	2209	2116.82	5	39	49.64
611514	F	23	1888	2189	2072.71	1868	2189	2077.25	20	0	-4.54
601067	F	64	2029	2276	2189.66	2012	2274	2180.79	17	2	8.87
608329	F	23	1961	2214	2102.65	1941	2299	2163.47	20	-85	-60.82
267110	M	49	1829	2186	2037.16	1843	2192	2026.28	-14	-6	10.9
638855	F	68	1725	2085	1933.25	1764	2133	1972.41	-39	-48	-39.16
605312	F	55	1832	2228	2065.94	1772	2223	2038.93	60	5	27.01
625925	F	26	1440	2378	2080.72	1401	2352	2055.75	39	26	24.97
601292	M	68	1725	2147	1953.13	1725	2178	1993.57	0	-31	-40.44
567056	M	59	1832	2279	2059.72	1806	2228	2028.4	26	51	31.32
632994	M	50	1874	2248	2090.13	1865	2231	2091.87	9	17	-1.74
582373	F	75	1640	1978	1824.01	1609	1975	1832.61	31	3	-8.6
582780	M	77	1651	2133	1885.55	1629	2138	1880.4	22	-5	5.15
661968	F	53	1882	2259	2121.18	1801	2265	2110.68	81	-6	10.5
667722	M	21	1891	2192	2062.22	1910	2195	2068.61	-19	-3	-6.39
643105	M	50	1573	2017	1825.19	1525	2091	1836.37	48	-74	-11.18
595011	M	29	1820	2203	2027.96	1803	2200	2037.63	17	3	-9.67
666553	M	35	1665	2057	1874.59	1620	2076	1862.65	45	-19	11.94
666541	M	38	1803	2127	1966.23	1795	2102	1965.92	8	25	0.31
660893	F	49	1710	2290	2025.34	1702	2302	2003.58	8	-12	21.76
650447	M	55	1680	2324	2104.51	1609	2310	2105.47	71	14	-0.96
665206	M	43	1781	2192	2028.47	1809	2155	2010.36	-28	37	18.11
665182	M	30	1834	2228	2083.15	1860	2228	2071.68	-26	0	11.47

436420	F	56	1772	2167	1975.79	1750	2121	1976.05	22	46	-0.26
615762	F	43	1792	2217	2023.51	1789	2240	2038.97	3	-23	-15.46
650467	F	54	1770	2302	2124.08	1702	2341	2136.89	68	-39	-12.81
656637	F	70	1722	2068	1897.95	1702	2062	1902.05	20	6	-4.1
635676	M	60	1789	2172	2024.78	1786	2209	2029.36	3	-37	-4.58
696150	F	58	1446	1913	1689.71	1446	1891	1693.53	0	22	-3.82
678743	F	72	1696	2040	1895.2	1702	2034	1893.01	-6	6	2.19
694042	F	30	1654	2158	2039.96	1851	2192	2022.48	-197	-34	17.48
679418	F	32	1480	2082	1870	1457	2228	1895.35	23	-146	-25.35
626671	F	56	1634	1908	1790.07	1632	1964	1792.95	2	-56	-2.88
229756	F	73	1654	1930	1802.53	1634	1939	1791.15	20	-9	11.38
700488	M	45	1851	2265	2071.26	1784	2307	2079.75	67	-42	-8.49
729542	F	45	1508	1967	1766.05	1513	1984	1775.16	-5	-17	-9.11
711348	F	49	1677	2274	2050.16	1651	2279	2060.9	26	-5	-10.74
654430	M	47	1477	2060	1733.54	1511	2062	1763.87	-34	-2	-30.33
704920	F	38	1578	1953	1801.61	1550	1953	1808.38	28	0	-6.77
541407	F	64	1615	1958	1801.49	1587	1964	1776.44	28	-6	25.05
702583	M	79	1936	2178	2065.37	1924	2200	2088.88	12	-22	-23.51
544874	F	86	1750	2147	1984.43	1722	2133	1973.67	28	14	10.76
184029	F	77	1634	2209	2040.12	1615	2262	2022.53	19	-53	17.59
725867	F	40	1634	2012	1870.53	1668	2040	1898.95	-34	-28	-28.42
743087	M	83	1471	1860	1693.59	1519	1896	1713.74	-48	-36	-20.15
742434	F	21	1832	2164	2010.15	1801	2189	2019.63	31	-25	-9.48
734370	M	36	1632	2144	1966.93	1629	2214	1948.25	3	-70	18.68
498189	M	31	1615	2062	1842.32	1615	1950	1804.77	0	112	37.55
608780	M	80	1888	2186	2055.8	1877	2141	2020	11	45	35.8
473758	F	73	1632	1916	1793.5	1626	1939	1797.19	6	-23	-3.69
791905	M	19	1888	2167	2026.85	1854	2158	2036.89	34	9	-10.04
744853	M	30	1770	2200	2015.1	1795	2220	2069.59	-25	-20	-54.49

747097	M	53	1761	2133	1990.42	1795	2113	1983.54	-34	20	6.88
757955	M	68	1767	2065	1927.24	1750	2110	1960.6	17	-45	-33.36
703826	M	43	1888	2167	2046.43	1910	2169	2063.01	-22	-2	-16.58
764027	F	57	1626	1910	1761.54	1646	1936	1790.9	-20	-26	-29.36
726286	F	56	1716	2234	2021.52	1733	2274	2004.78	-17	-40	16.74
787854	F	58	1584	2127	1909.86	1595	2147	1975.36	-11	-20	-65.5
334142	F	37	1702	2068	1910.98	1702	2068	1913.02	0	0	-2.04
774777	M	28	1680	2000	1848.71	1674	2012	1855.64	6	-12	-6.93
779285	F	31	1705	1961	1840.62	1713	2009	1877.94	-8	-48	-37.32
360421	M	66	1792	2121	1991.82	1744	2141	1977.12	48	-20	14.7
780336	M	31	1733	2015	1886.34	1699	1995	1858.43	34	20	27.91
713521	F	73	1815	2158	2009.5	1823	2169	2055.21	-8	-11	-45.71
771861	M	25	1930	2172	2070.77	1927	2150	2049.03	3	22	21.74
779895	F	56	1587	1964	1838.21	1595	1964	1805.86	-8	0	32.35
706375	M	50	1595	1992	1850.86	1587	1992	1839.24	8	0	11.62
745025	M	64	1984	2220	2111.51	1930	2240	2123.3	54	-20	-11.79
801933	M	50	1443	1888	1683.3	1423	1865	1677.44	20	23	5.86
782424	F	72	1480	2065	1776.76	1492	2048	1749.56	-12	17	27.2
555106	M	42	1471	1896	1678.15	1415	1882	1645.34	56	14	32.81
704776	F	55	1494	1865	1681.65	1519	1891	1692.4	-25	-26	-10.75
802601	M	37	1308	1823	1557.79	1280	1826	1555.14	28	-3	2.65
808233	F	31	1418	1905	1598.03	1406	1920	1597.81	12	-15	0.22
801936	M	56	1761	2091	1953.89	1747	2082	1944.59	14	9	9.3
803262	F	62	1764	2093	1940.46	1761	2110	1956.02	3	-17	-15.56
746003	F	75	1713	2026	1879.31	1736	2031	1882.99	-23	-5	-3.68
810784	M	48	1404	1860	1658.61	1423	1860	1624.16	-19	0	34.45
808256	M	50	1511	1865	1693.33	1519	1868	1691.94	-8	-3	1.39
804423	F	80	1865	2189	2056.62	1840	2183	2040.35	25	6	16.27
775209	F	52	1722	1992	1867.41	1736	2023	1917.66	-14	-31	-50.25

803599	M	23	1798	2062	1954.79	1781	2045	1937.9	17	17	16.89
808721	M	21	1877	2198	2049	1888	2167	2027.24	-11	31	21.76
646298	M	90	1730	2003	1880.06	1713	2045	1908.67	17	-42	-28.61
860869	M	49	1595	2003	1817.07	1527	2093	1815.86	68	-90	1.21
860844	F	52	1603	1975	1823.32	1603	2031	1836.15	0	-56	-12.83
740307	M	67	1429	2110	1817.26	1412	2142	1829.44	17	-32	-12.18
866295	F	27	1649	1950	1819.89	1646	1975	1843.14	3	-25	-23.25
711348	F	53	1423	1984	1725.49	1412	2014	1745.34	11	-30	-19.85
865850	M	20	1778	2085	1953.36	1792	2105	1949.92	-14	-20	3.44
865358	F	33	1716	2034	1897.73	1730	2043	1906.14	-14	-9	-8.41
843952	F	23	1786	2093	1980.39	1764	2082	1960.97	22	11	19.42
368044	M	27	1243	2228	1831.37	1257	2259	1802.87	-14	-31	28.5
713492	F	60	1801	2085	1961.48	1764	2099	1986.71	37	-14	-25.23
850877	F	67	1685	2003	1864.49	1663	2009	1843.53	22	-6	20.96
675860	M	56	1542	2116	1783.01	1618	2029	1862.75	-76	87	-79.74
716467	M	12	1553	2074	1854.67	1550	2085	1891.02	3	-11	-36.35
286504	F	20	1978	2310	2208.66	1927	2355	2239.87	51	-45	-31.21
773087	M	42	1595	2012	1814.97	1710	2096	1936.98	-115	-84	-122.01
759839	M	50	1651	2093	1870.72	1634	2110	1952.78	17	-17	-82.06
652972	M	36	1764	2228	1968.12	1736	2240	2057.2	28	-12	-89.08
676360	F	21	1620	2065	1892.27	1626	1986	1812.13	-6	79	80.14
865377	M	80	1553	1927	1740.77	1482	1955	1737.49	71	-28	3.28
859554	M	41	1702	2091	1940.71	1730	2065	1938.36	-28	26	2.35
655031	F	24	1511	1998	1815.43	1550	2034	1834.78	-39	-36	-19.35
706396	M	41	1359	1854	1572.31	1381	1806	1604.04	-22	48	-31.73
658749	F	62	1806	2251	2064.22	1817	2265	2061.87	-11	-14	2.35
689329	F	52	1375	1750	1572.66	1406	1733	1585.05	-31	17	-12.39
803239	F	47	1815	2178	2013.8	1837	2155	2027.66	-22	23	-13.86
672166	M	55	1556	2119	1817.8	1587	2169	1886.51	-31	-50	-68.71

613292	F	76	1674	2082	1897.74	1632	2072	1875.4	42	10	22.34
599369	M	78	1553	1840	1696.09	1561	1862	1714.31	-8	-22	-18.22
404644	M	44	1784	2209	2002.75	1803	2178	1978.59	-19	31	24.16

Table 7. Statistical significance verification of age distribution between osteomyelitis patient and control group

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
avg	Equal variances assumed	3.438	0.065	-6.087	210.000	0.000	-14.618	2.401	-19.352	-9.884
	Equal variances not assumed			-6.176	209.011	0.000	-14.618	2.367	19.284	-9.953

$p < 0.01$, reject null hypothesis and there is difference between two groups

Table 8. Location of osteomyelitis lesion

Classification of lesion / Location of lesion	Osteoradionecrosis	BRONJ	Bacterial osteomyelitis	Total (Osteomyelitis)
Rt mand.	2	14	28	44
Lt mand.	1	8	21	30
Rt max.	0	3	2	5
Lt max.	0	2	4	6
Ant mand.	0	2	0	2
Ant max.	0	1	0	1
Lt&Rt mand.	1	1	4	6
Lt&Rt max&mand.	0	0	1	1
Total	4	31	60	95

Table 9. Treatment of osteomyelitis patient

Treatment	Osteoradio-necrosis	BRONJ	Bacterial osteomyelitis	Total (osteomyelitis)
Saucerization	3	21	26	50
Medicine	0	2	6	8
Mandibulectomy / maxillectomy	1	2	4	7
Sequestrectomy	0	3	3	6
Mass resection	0	1	1	2
Incision and Drainage	0	1	2	3
Extraction	0	0	3	3
Cyst enucleation	0	0	3	3
Endodontic treatment	0	0	1	1
Untreated	0	1	11	12
Total	4	31	60	95

Table 10. Significance verification of comparison between ostemomyelitis patient and control group(WNL)

		Predicted					
		WNL	OM	WNL	Suppurative OM	WNL	Sclerosing OM
Actual	WNL	16	0	23	0	23	2
	Osteomyelitis	5	21	3	5	0	9
Accuracy			88.1%		96.8%		94.1%

Table 11. Statistical significance verification of average photographic density difference (Avg) between Suppurative type osteomyelitis and Sclerosing type osteomyelitis

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
avg	Equal variances assumed	3.019	0.086	12.625	89.000	0.000	274.623	21.752	231.403	317.843
	Equal variances not assumed			13.195	87.562	0.000	274.623	20.813	233.258	315.988

$p < 0.01$, reject null hypothesis and there is difference between two groups

Table 12. Statistical significance verification of maximum photographic density difference (Max) between Suppurative type osteomyelitis and Sclerosing type osteomyelitis

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
avg	Equal variances assumed	0.047	0.829	10.133	89.000	0.000	188.088	18.562	151.205	224.971
	Equal variances not assumed			10.280	87.572	0.000	188.088	18.297	151.724	224.452

$p < 0.01$, reject null hypothesis and there is difference between two groups

Table 13. Statistical significance verification of minimum photographic density difference (Min) between Suppurative type osteomyelitis and Sclerosing type osteomyelitis

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
avg	Equal variances assumed	0.718	0.399	9.182	89.000	0.000	262.924	28.633	206.030	319.817
	Equal variances not assumed			9.549	88.365	0.000	262.924	27.533	208.211	317.636

$p < 0.01$, reject null hypothesis and there is difference between two groups

Table 14. Statistical significance verification of average photographic density difference (Avg) among suppurative type (B1 / C1) in BRONJ and bacterial osteomyelitis

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
avg	Equal variances assumed	0.641	0.428	0.398	38.000	0.693	10.315	25.887	-42.090	62.721
	Equal variances not assumed			0.389	32.232	0.699	10.315	26.485	-43.618	-64.249

p > 0.01, accept null hypothesis and there is no difference between two groups

Table 15. Statistical significance verification of maximum photographic density difference (Max) among suppurative type (B1 / C1) in BRONJ and bacterial osteomyelitis

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
avg	Equal variances assumed	0.810	0.374	0.686	38.000	0.497	17.980	26.226	-35.112	71.072
	Equal variances not assumed			0.672	32.921	0.506	17.980	26.745	-36.438	72.398

p > 0.01, accept null hypothesis and there is no difference between two groups

Table 16. Statistical significance verification of minimum photographic density difference (Min) among suppurative type (B1 / C1) in BRONJ and bacterial osteomyelitis

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
avg	Equal variances assumed	0.320	0.575	-0.084	38.000	0.934	-2.949	35.286	-74.382	68.483
	Equal variances not assumed			-0.082	33.730	0.935	-2.949	35.842	-75.811	69.912

p > 0.01, accept null hypothesis and there is no difference between two groups

Table 17. Statistical significance verification of average photographic density difference (Avg) among sclerosing type (B2 / C2) in BRONJ and bacterial osteomyelitis

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
avg	Equal variances assumed	1.032	0.315	-1.515	49.000	0.136	-64.579	42.627	-150.240	21.082
	Equal variances not assumed			-1.968	16.923	0.066	-64.579	32.811	-133.828	4.670

p > 0.01, accept null hypothesis and there is no difference between two groups

Table 18. Statistical significance verification of maximum photographic density difference (Max) among sclerosing type (B2 / C2) in BRONJ and bacterial osteomyelitis

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
avg	Equal variances assumed	0.337	0.564	-2.446	49.000	0.018	-79.024	32.314	-143.961	-14.087
	Equal variances not assumed			-2.652	12.798	0.020	-79.024	29.803	-143.513	-14.534

p > 0.01, accept null hypothesis and there is no difference between two groups

Table 19. Statistical significance verification of minimum photographic density difference (Min) among sclerosing type (B2 / C2) in BRONJ and bacterial osteomyelitis

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
avg	Equal variances assumed	1.667	0.203	-1.274	49.000	0.209	-71.048	55.777	-183.135	41.040
	Equal variances not assumed			-2.048	28.671	0.050	-71.048	34.686	-142.025	-0.070

p > 0.01, accept null hypothesis and there is no difference between two groups

Figure Legends

Figure 1. Measuring method using 'Measure area rectangle' of Infinitt PACS : bacterial osteomyelitis patient 10th in table 5.

Figure 2. Comparing method of photographic density in patient with osteomyelitis: focus in left mandible and WNL in right mandible. : bacterial osteomyelitis patient 12th in table 5.

Figure 3. Maximum and minimum photographic density in panoramic radiograph : bacterial osteomyelitis patient 17th in table 5.

Figure 4. Comparing method of photographic density in normal patient : normal patient(control group, WNL) 9th in table 6.

Figure 5. Panoramic radiograph of the same patient above taken another day. normal patient(control group, WNL) 9th in table 6.

Figure 6. Conditional inference tree: Comparison between Osteomyelitis patient group with control group(WNL)

Figure 7. Conditional inference tree: Comparison between Bacterial Osteomyelitis + BRONJ(Suppurative type, B1+C1) and control group(WNL)

Figure 8. Conditional inference tree: Comparison between Osteoradionecrosis + Bacterial Osteomyelitis + BRONJ(Sclerosing type, B2+C2) and control group(WNL)

Figure 9. Diagnosis model using quantitative analysis of panoramic radiograph

Figures

Figure 1.

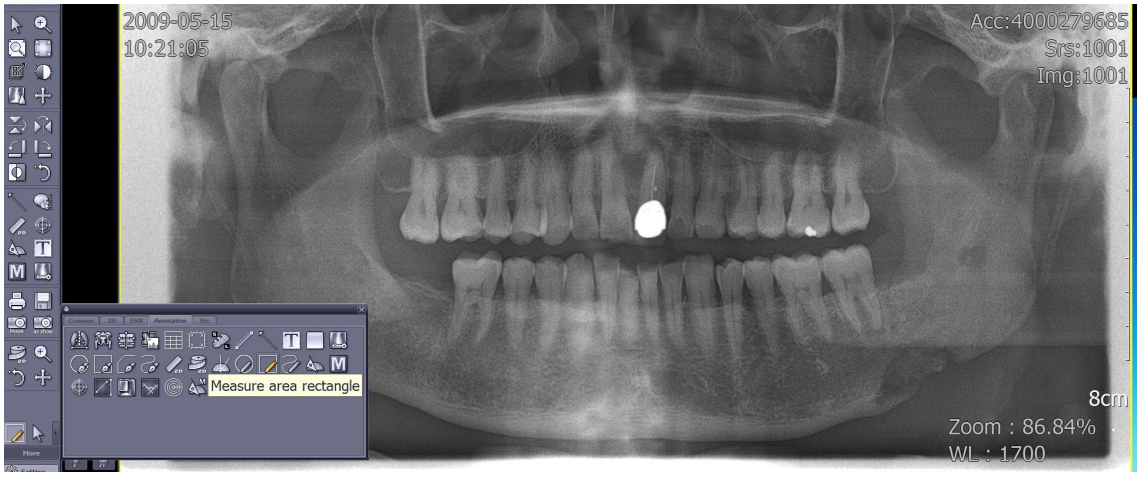
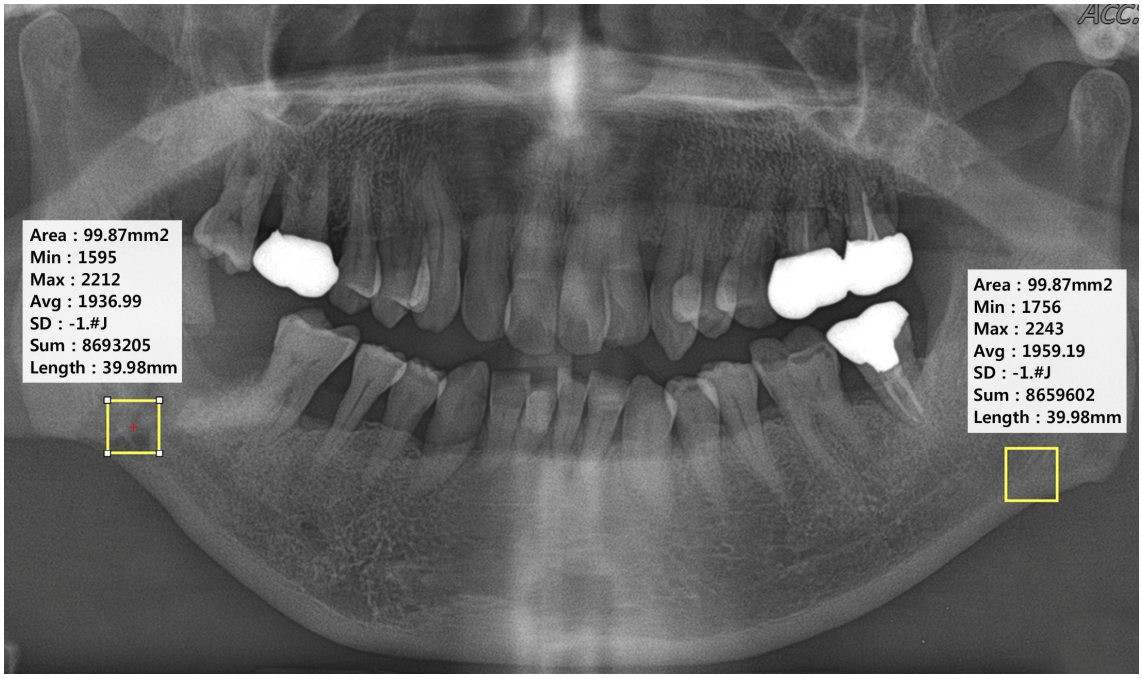


Figure 2.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Max : 2212
Avg : 1936.99
SD : -1.#J
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SD : -1.#J
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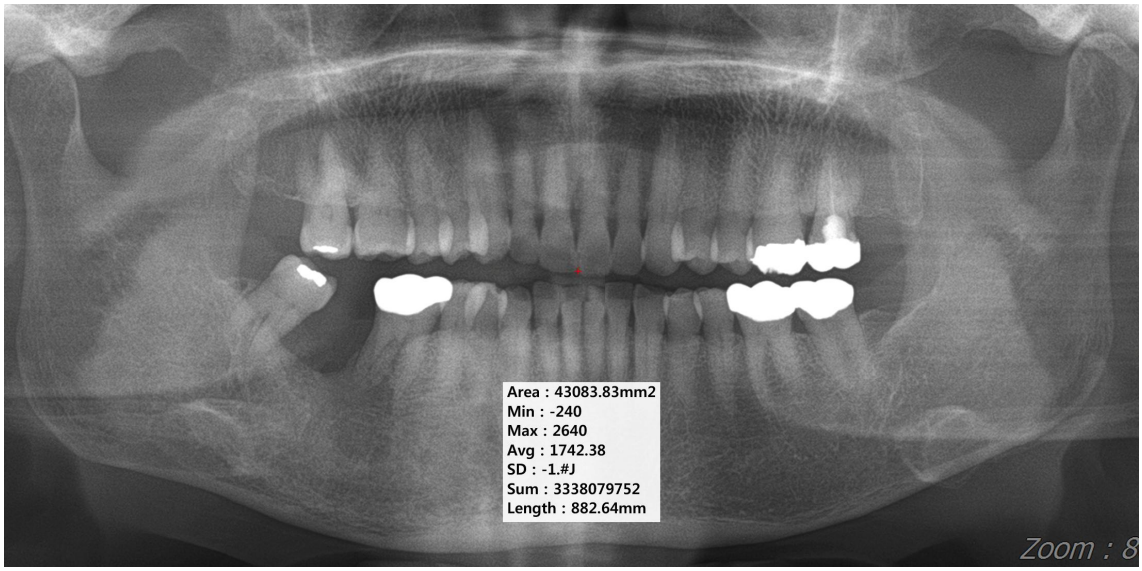
Length : 39.98mm

Figure 3.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Min : -240
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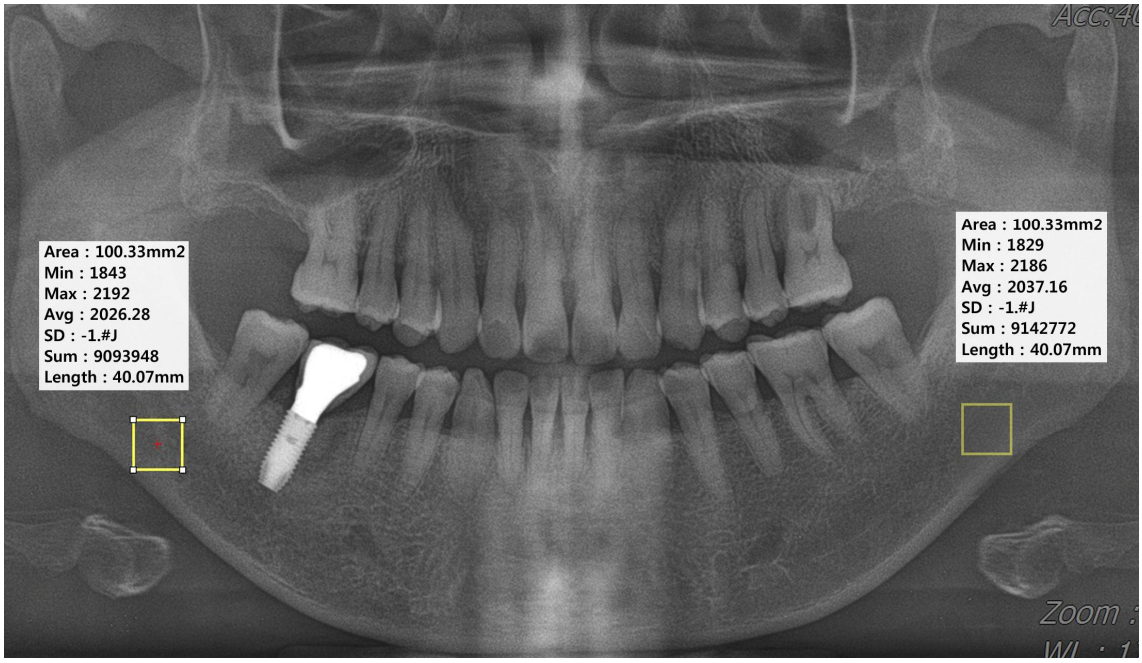
Length : 882.64mm
Zoom : 8

Figure 4.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Avg : 2037.16
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Length : 40.07mm

Figure 5.

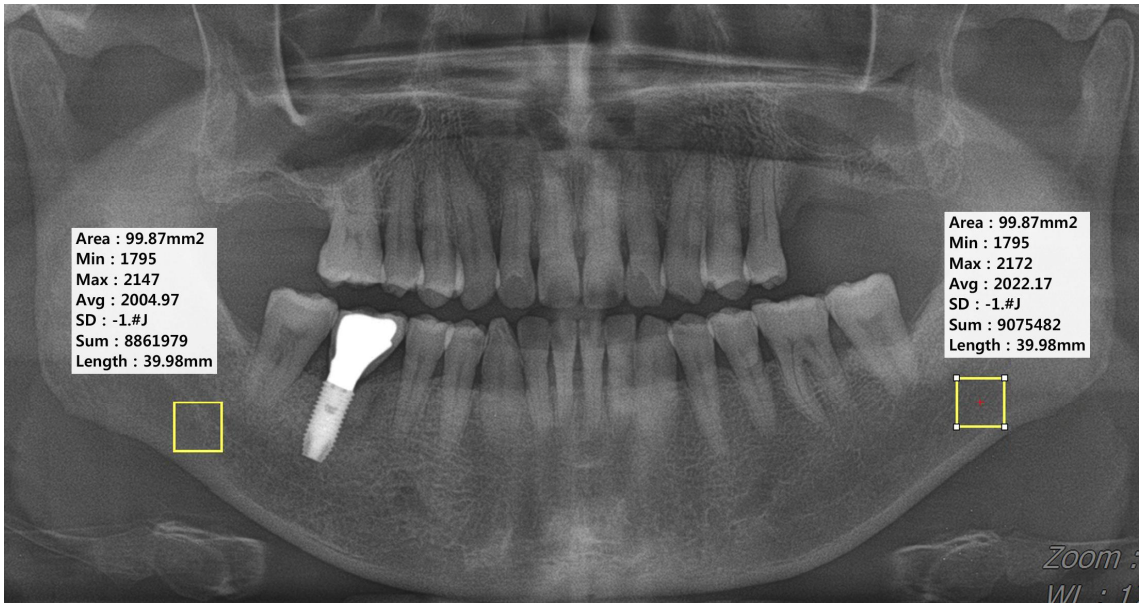
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Figure 6.

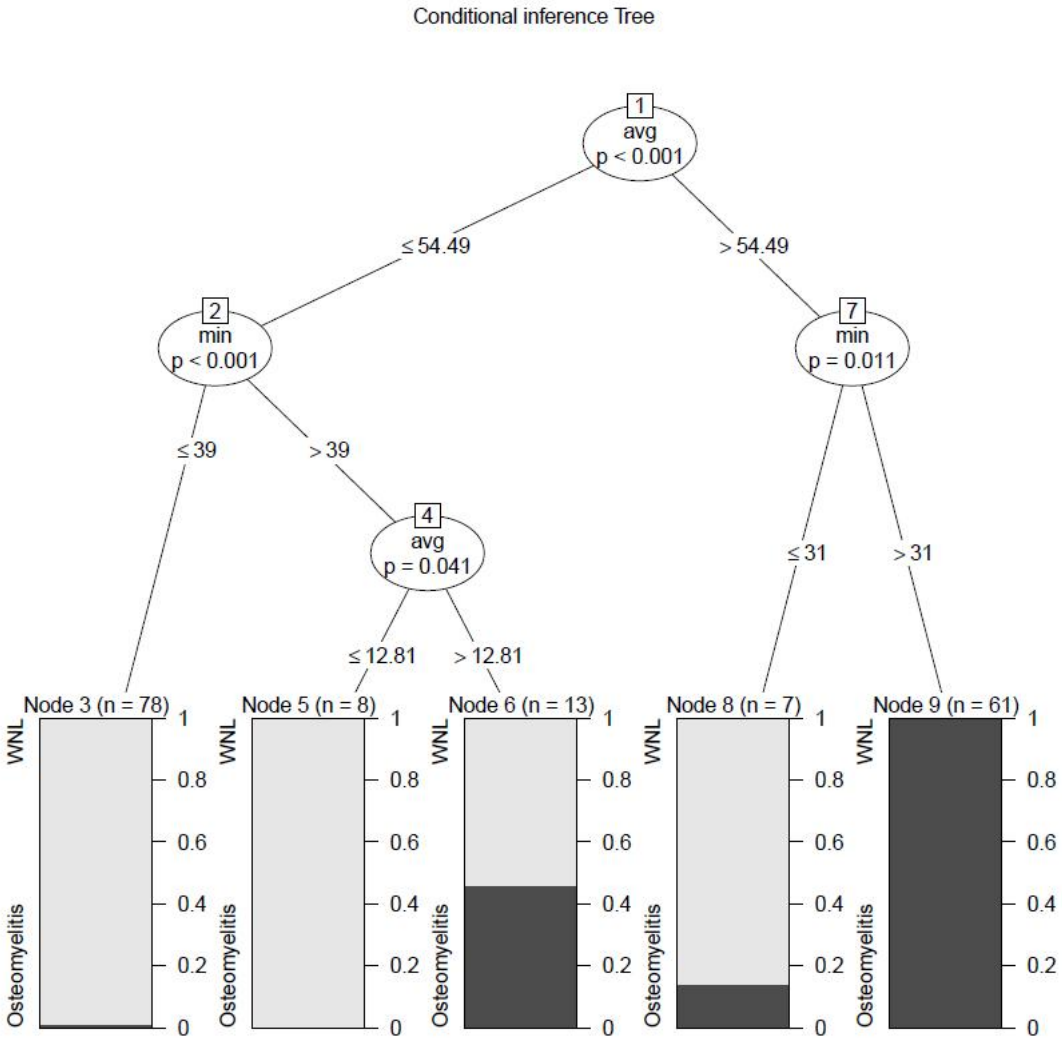

Conditional inference Tree
1
avg
p < 0.001
≤ 54.49
> 54.49
2
min
p < 0.001
7
min
p = 0.011
≤ 39
> 39
4
avg
p = 0.041
≤ 31
> 31
≤ 12.81
> 12.81
Node 3 (n = 78)
Node 5 (n = 8)
Node 6 (n = 13)
Node 8 (n = 7)
Node 9 (n = 61)
WNL
Osteomyelitis
1
0.8
0.6
0.4
0.2
0

Figure 7.

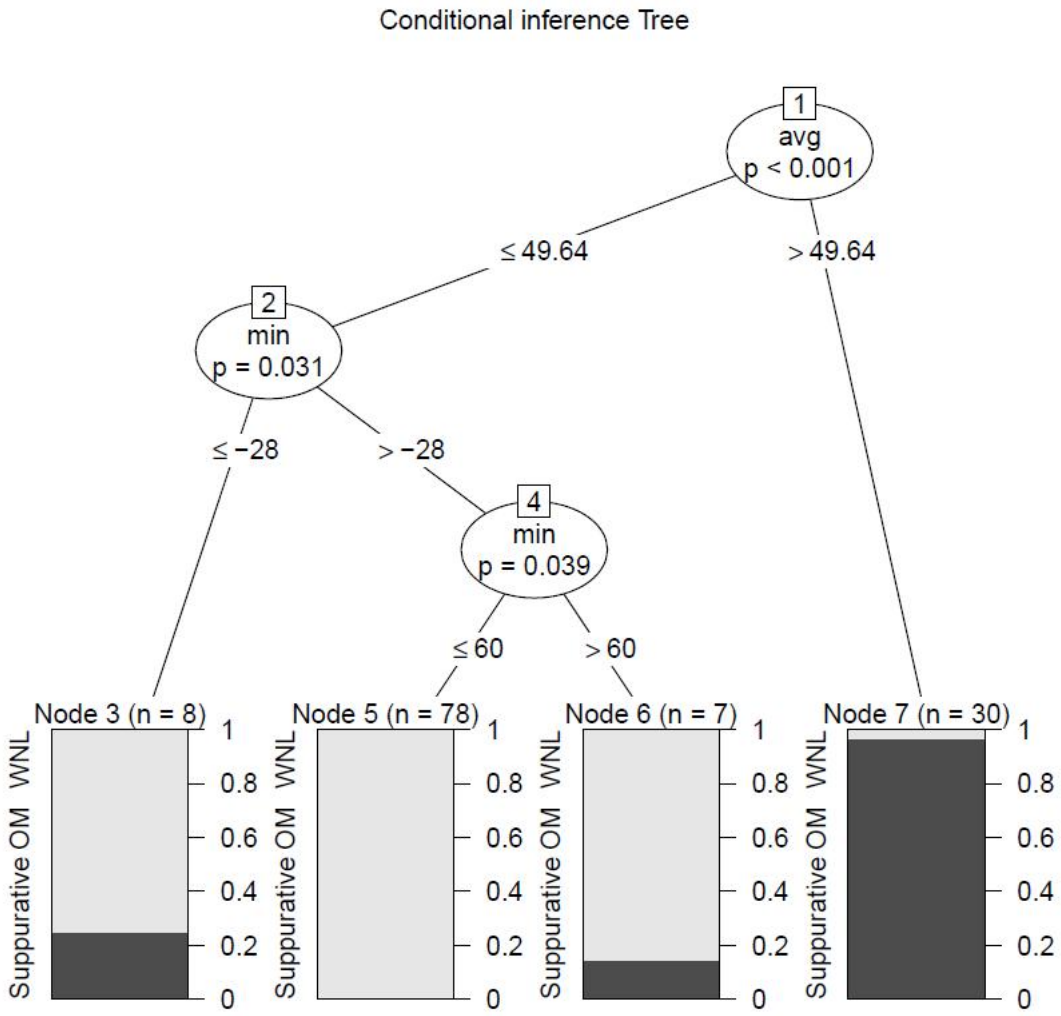

Conditional inference Tree
1
avg
p < 0.001
≤ 49.64
> 49.64
2
min
p = 0.031
≤ −28
> −28
4
min
p = 0.039
≤ 60
> 60
Node 3 (n = 8)
Node 5 (n = 78)
Node 6 (n = 7)
Node 7 (n = 30)
Suppurative OM WNL
0
0.2
0.4
0.6
0.8
1

Figure 8.

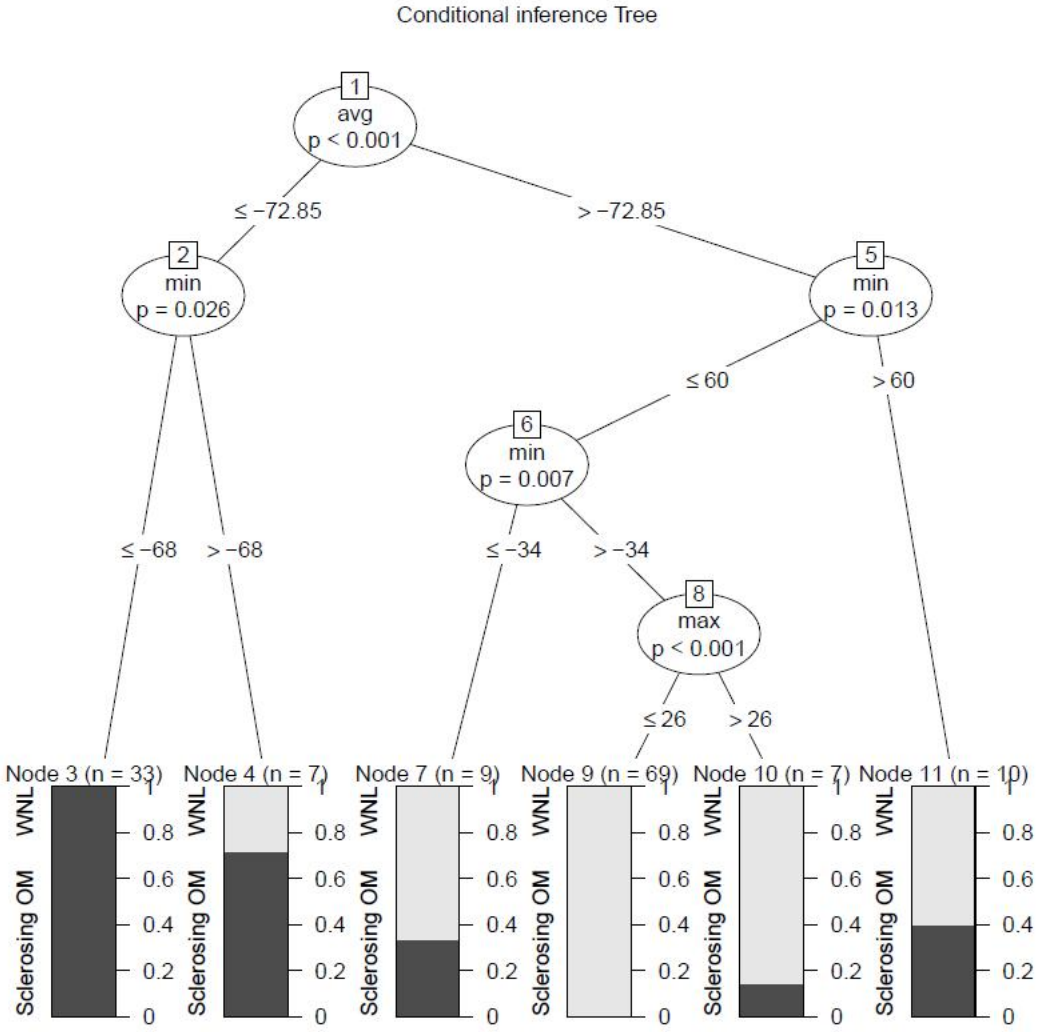
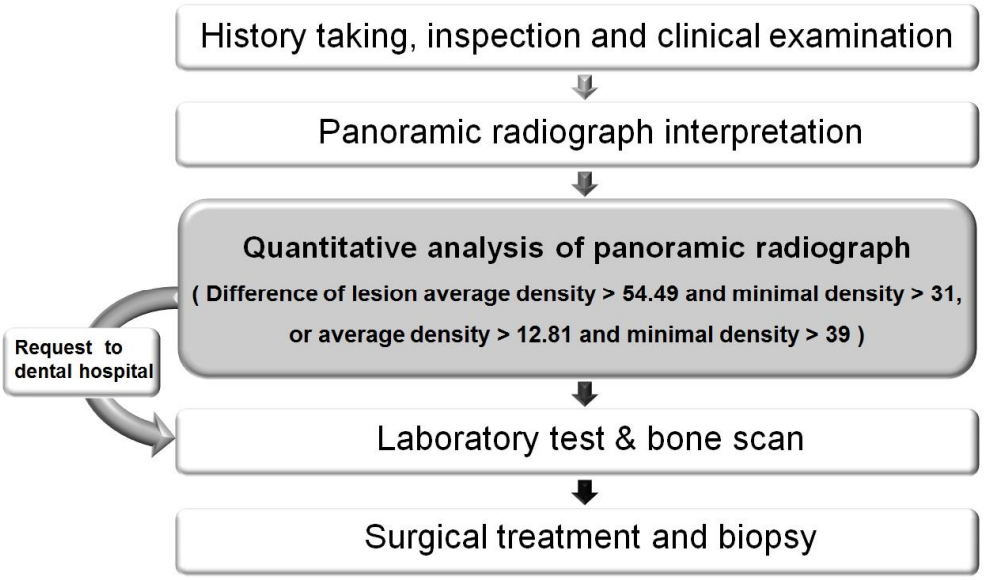

Conditional inference Tree
1
avg
p < 0.001
≤ −72.85
> −72.85
2
min
p = 0.026
5
min
p = 0.013
≤ 60
> 60
6
min
p = 0.007
≤ −68
> −68
≤ −34
> −34
8
max
p < 0.001
≤ 26
> 26
Node 3 (n = 33)
Node 4 (n = 7)
Node 7 (n = 9)
Node 9 (n = 69)
Node 10 (n = 7)
Node 11 (n = 10)
WNL
Sclerosing OM
0
0.2
0.4
0.6
0.8
1

Figure 9.


History taking, inspection and clinical examination
Panoramic radiograph interpretation
Quantitative analysis of panoramic radiograph
(Difference of lesion average density > 54.49 and minimal density > 31,
or average density > 12.81 and minimal density > 39)
Request to dental hospital
Laboratory test & bone scan
Surgical treatment and biopsy

국문초록

파노라마 영상 분석을 통한 악골 골수염의 조기 진단

박 무 성

치의학과

치의학전문대학원

서울대학교

악골 내에 생기는 염증성 질환으로, 점진적인 염증성 골파괴와 골조직의 침착을 특징으로 하는 악골 골수염의 가장 대표적인 병인은 세균의 감염이며 외상, 방사선 조사나 특정 약물에 의해서도 발생된다. 의학의 발달과 구강위생의 증진은 악골 골수염의 유병율을 감소시켜 왔으나 약물 또는 방사선 치료 등에 의해 이차적으로 유도되는 형태의 악골 골수염인 비스포스포네이트관련 악골괴사나 방사선 골괴사가 발생하여 왔다.

치과의원에서 기본적인 치료과정인 파노라마를 통해 골수염의 판독을 보조하는 수단으로서 정량적인 분석 수단의 활용 가능성을 고려할 수 있는데, 이에 본 연구에서는 별도의 소프트웨어나 프로그램 없이 방사선 영상을 보여주는 프로그램인 의료영상저장전송시스템에서 제공하는 기본 기능만을 이용하여 파노라마 방사선 영상 상에서 골수염을 조기진단 하는 것을 그 목적으로 하였다.

2008년부터 2017년까지 총 11년 간 서울대학교치과병원 구강악안면외과의 한명의 외과의사에서 임상적, 방사선학적 및 병리학적 진단 하에 골수염으로 확진된 환자 95명을 대상으로 하였다. 이들 골수염 환자들을 각각 방사선 골괴사, 비스포스포네이트관련 악골괴사 및 세균성 골수염 (화농성 및 경화성) 등과 같이 모두 5가지 범주로 분류하였다. INFINITT PACS®(INFINITT Healthcare, Seoul,

Korea)에 있는 Measure area rectangle을 이용하여 5분류 환자의 파노라마를 정중선을 기준으로 좌우로 구분하여 양측의 흑화도를 비교하였다. 대조군으로는 역시 동일 기간내에 골수염 진단을 받지 않은 환자 중 무작위로 추출한 117명의 파노라마 영상에서 분석하였다.

통계 처리는 통계프로그램R (https://www.r-project.org) 을 이용하여 의사결정나무의 한 종류인 조건적 추론나무를 제작하였으며, 임상적 범주 별로 상대적으로 흑화도의 변화 방향이 같은 양상은 SPSS statistical software® (Version16.0, SPSSInc.)를 이용하여 t-검정을 시행하였다.

골수염 환자군을 대조군과 비교하여 만든 의사결정나무는 흑화도 평균값의 차이가 54.49를 초과하고 흑화도 최소값의 차이가 31을 초과하는 경우 혹은 평균값이 12.81과 54.49 사이에 있으면서 최소값의 차이가 39를 초과하는 경우에 확정적으로 골수염으로 분류할 수 있었으며, 88.1%의 유의성 검정으로 질환을 분류할 수 있었다. 화농성 골수염군에서는 96.8%, 경화성 골수염군에서는 94.1%의 확률을 보였으며, 비스포스포네이트관련 악골괴사군와 세균성 골수염군에서는 각각 화농성 및 경화성 골수염군과 집단끼리 t-검정한 결과, 두 질환에서 흑화도 차이값의 유의미는 보이지 않았다.

이는 기존의 연구들에서 두 질환의 방사선학적 특징을 세분하려고 시도했으나 결과를 얻지 못하는 것과 유사함을 확인하였고, 본 연구 방법을 이용하면 프로그램상의 기본적인 기능만으로 흑화도를 측정하고 이를 진단의 보조 수단으로 이용할 수 있다는 것을 확인할 수 있었다.

주요어 : 조기 진단, 파노라마 영상 분석, 악골 골수염, 의사결정나무

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